CHAPTER 13: COMMON PROPERTY RESOURCES AND PUBLIC GOODS

The theory of externalities, presented in the previous chapter, provides us with a powerful example of market failure, in which unregulated markets fail to produce an efficient outcome. In this chapter we consider other examples of market failure. In some cases, a market may exist but be economically inefficient due to limited property rights. In other cases, a market doesn't even exist, for example when social or environmental resources are not owned or ownership rights are not clear. Some important examples are:

- The oceans, which generally are not subject to private property rights and are not controlled by individual countries, except in coastal zones. The world's oceans contain some of the most important planetary ecosystems. Healthy fisheries are a critical source of food for the world's population, supplying an important source of protein for many lower-income people.
- Many forested areas and wetlands are not privately owned. They may be public lands managed by government agencies or local communities, or there may be no clearly established ownership.
- The earth's atmosphere is crucial to all of us but is owned by nobody. Atmospheric functions include the carbon cycle that supports both plant and animal life, climate stabilization, and parts of the water cycle—all critical to planetary ecology. The issue of climate change has become particularly important in recent years, and is one that we will focus on later in this chapter.
- Public parks, public beaches, river and lake fisheries, and many recreational areas contribute to well-being but are generally provided without established private markets.
- A slightly different kind of example is public airwaves, which are often available for use by private companies under rules set by government.

This chapter provides further insights into economic policies concerning issues such as ocean fisheries, climate change, public parks, and public airwaves. In each of these cases, we discuss why a market failure exists and suggest policy responses that can increase the well-being of society.

1. GOODS OTHER THAN PRIVATE GOODS

In previous chapters, we discussed economic activities related to **private goods**. A private good can be defined as having two distinguishing characteristics:

1. A private good is **excludable**. This means that owners of the good can prevent others from consuming it or enjoying its benefits. For example, the textbooks that you own are excludable goods because, if you wish, you can prevent anyone else from using them. Generally, purchasing a private good establishes an owner's legal right to exclude others from accessing the good.
2. A private good is **rival**. This means that a unit of the good can be consumed by only one person at a time. So, if you are wearing a shirt, no one else can wear that shirt at the same time.

private good: a good that is excludable and rival

excludable good: a good whose consumption by others can be prevented by its owner(s)
rival good: a good that can only be consumed by only one person at a time

It will help us understand the concept of a private good if we contrast it with three other types of goods: public goods, common property resources, and artificially scarce goods.

As we mentioned in Chapter 2, a **public good** is one that is freely available to anyone, and whose use by one person does not diminish its usefulness to others. Economists use the terms **nonexcludable** and **nonrival** to define a public good. This means that no one can be excluded from consuming it because they did not pay for it and that more than one person at a time can enjoy its benefits. An important economic result is that, because many people can simultaneously enjoy a nonrival good at the same time, the marginal cost of providing it to one more person is zero.

public good: a good whose benefits are freely available to anyone (nonexcludable), and whose use by one person does not diminish its usefulness to others (nonrival)
nonexcludable good: a good whose benefits are freely available to all users
nonrival good: a good that can be consumed by more than one person at a time. The marginal cost of providing a nonrival good to an additional person is zero

A common example of a public good is national defense—everyone in a country can simultaneously receive its benefits, and none can be excluded. Another example is a national park, because it is freely available to everyone, and many people can enjoy it at the same time. (Some national parks do charge a small entry fee, but these fees rarely present a significant barrier for visitors. So, for practical purposes they are available for everyone's enjoyment.)

Some people mistakenly consider any good "owned" or managed by a government a public good. But a natural reserve managed by an environmental group may also meet the qualifications of a public good, while some public resources may be managed by governments as private goods. An example would be a plot of public grazing land that is leased exclusively to the highest-bidding rancher.

Second, **common property resources** are nonexcludable but rival. In other words, common property resources can be freely consumed or enjoyed by anyone, but their use by one person diminishes their availability to others. A classic example of a common property resource is the stock of fish in an open ocean fishery. Anyone with a boat can catch as much fish as he or she is able to. However, fish caught by one fisher are not available to be caught by anyone else. Also, as we will discuss in more detail, overuse of the fishery could eventually reduce its availability to all.

common property resource: a resource that is nonexcludable and rival

Some resources may be classified as both a common property resource and a public good, depending on the circumstances. We mentioned above that a national park can be considered a public good. But if the park becomes so crowded that the benefits to each visitor start to decline, then we can say that the park no longer meets the strict definition of a nonrival good. In other words, the availability or quality of a common property resource eventually declines when demands on it increase. But a public good remains available in undiminished quality despite increasing demands.

Finally, we have **artificially scarce goods**, which are excludable but nonrival.[1] Thus artificially scarce goods can be simultaneously consumed by many people at a time, but those who do not pay can be excluded from enjoying the good. An example of an artificially scarce good is a toll road. Those who do not pay the toll can be excluded from using the road, but (at least up to a point) many people can simultaneously use the road.

artificially scarce good: a good that is excludable but nonrival

We can classify different goods into four basic categories as shown in Table 13.1, with examples for each type of good. The boundary between these categories is not always clear; particular goods often display characteristics along a spectrum from rival to nonrival and from excludable to nonexcludable. Many goods are subject to **congestion,** meaning that they are nonrival if relatively few people use them at once, but when demand reaches a certain level each user's benefit begins to decrease due to crowding or scarcity (as with a toll road or ocean fishery).

Table 13.1. Classification of Different Types of Goods

	Excludable	Nonexcludable
Rival	**Private goods:** T-shirts, groceries, cars, cell phones, haircuts	**Common property resources:** ocean fisheries, groundwater, a community basketball court
Nonrival	**Artificially scarce goods:** cable television, computer software, toll roads	**Public goods:** national defense, free radio, public education, national parks

congestion: the point at which the demand for a nonrival good results in a diminished benefit to each user, and thus it becomes rival

Private goods are normally distributed through markets. This is also the case with artificially scarce goods—those who do not pay can be excluded from obtaining the good's benefits, so suppliers can obtain profits by selling it to those who are willing to pay. But some artificially scarce goods, such as toll roads, are provided by governments without necessarily yielding a profit.

Common property resources and public goods are often supplied or managed by governments. But other organizations can also provide goods or services that benefit everyone, such as advocacy work by environmental groups. Also, some resources may not be managed at all, such as a river with unregulated water withdrawals.

We have seen in other chapters that markets that provide private goods can suffer from market failure under some circumstances, such as when externalities exist. For the other three types of goods in Table 13.1 distribution via private markets *almost always results in market failure*. Thus, market intervention is often justified for these goods solely on the basis of economic efficiency. Intervention may also be justified on the basis of equity, environmental protection, and other final goals. We now turn to the economic theory and policy implications for each of these three types of goods.

Discussion Questions

1 In addition to the examples listed in Table 13.1, try to think of other instances of artificially scarce goods, common property resources, and public goods. Discuss how these goods are supplied—whether through markets, through government provision, or through other approaches.

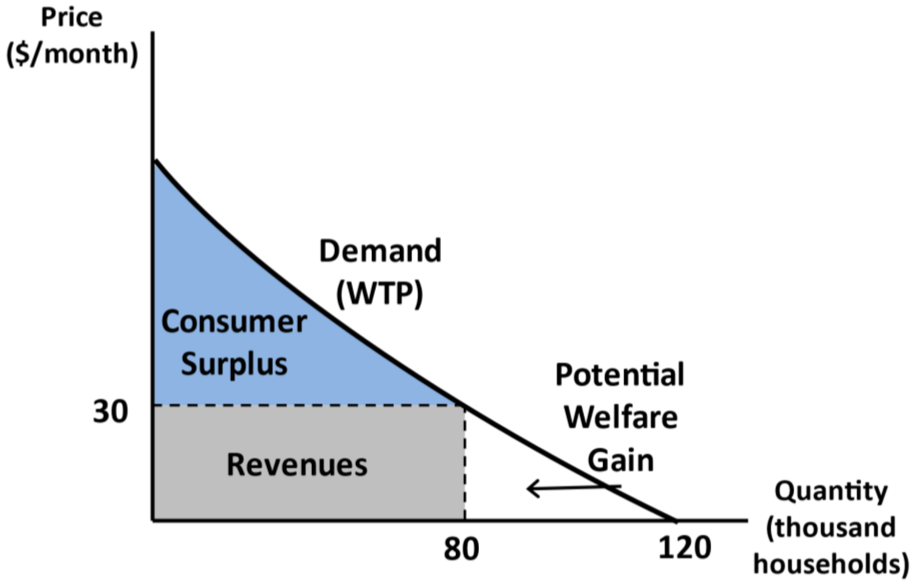
2 Do you think that the current balance in your society among the four different types of goods is appropriate? Should policies be enacted to shift production so that, in general, society has more public goods and common property resources? Or should more goods be made available instead through private markets? Can you think of specific policies that could achieve the kinds of shifts that you would favor?

2. ARTIFICIALLY SCARCE GOODS

In a market for a private good, the efficient level of provision occurs when the marginal benefits just equal the marginal costs, assuming no other market failures. But for an artificially scarce good, the marginal cost of providing it is generally zero, at least within a specific quantity range. For example, for homes equipped with cable television, the cost to the provider of sending the broadcast signal to one more household is essentially zero. For a movie theater, the cost of allowing one more person to watch a movie (assuming empty seats are available) is negligible. Note that this does not mean that total production costs are zero. The start-up cost of a cable television company or a movie theater can be quite high. Instead, what distinguishes artificially scarce goods from private goods is that their *marginal* supply costs are zero.

Figure 13.1 illustrates the market for an artificially scarce good, cable television. The demand curve shows the maximum willingness to pay for different households in the region. Assume the cable television company charges $30 per month for a basic cable subscription. At this price, 80,000 households sign up for the service, as shown in the graph. The revenues of the cable company are $2.4 million per month ($30 times 80,000 households). The consumer surplus in the market is represented by the shaded region above the price but below the demand curve.

Figure 13.1. The Market for an Artificially Scarce Good (Cable Television)



But you might note that something is missing from Figure 13.1—*there is no supply curve!* As the supply curve represents the marginal costs of providing the good, for an artificially scarce good, there is no supply curve. Or more precisely, the supply curve is a horizontal line at a price of zero.

If we apply our rule that social welfare is maximized when the marginal benefits are equal to the marginal costs, then the efficient quantity of cable television is provision to all 120,000 households that are willing to pay something for it. Note that if the cable company provided services at no cost to the 40,000 additional households that value it (but are not willing to pay $30/month), then total social welfare would increase by the triangle on the right-hand side of the graph.

Of course, the cable company will not do this. Profit-making companies rarely provide their goods and services for free. Instead, the cable TV company in Figure 13.1 will set its price to maximize its profits. The price it sets will depend on the elasticity of demand; recall our discussion in Chapter 4 about the relationship between elasticity and revenues.

The profit-maximizing price will not result in a level of provision that maximizes social welfare. In other words, the price set by the supplier of an artificially scarce good will leave some people still willing to pay for the product (but with a WTP below price) while the marginal cost is zero, leaving potential social benefits unrealized. Note that the company could theoretically attract additional customers by charging them a monthly fee of less than $30/month. However, this requires that the company engage in **price discrimination**—charging different customers a different price for the same good or service. So, while it would keep charging $30/month to most of its customers, the company might charge $10/month to other customers who have a lower willingness to pay. As the marginal cost of providing cable services is zero, the company's profits would increase nonetheless and those additional customers would obtain some consumer surplus, increasing economic efficiency.

price discrimination: the practice of charging different customers different prices for the same good or service

In most cases, price discrimination is either illegal or difficult to implement. But in some cases, price discrimination can result in both higher profits for the supplier and increased economic efficiency. Take the example of a movie theater that offers discounted ticket prices to students and seniors. If most students and seniors would not be able or willing to pay the undiscounted price, then the movie theater obtains more customers, and the welfare loss triangle in Figure 13.1 can be reduced.

Another example of price discrimination occurs with computer software programs. Programs such as Microsoft Office are artificially scarce goods because the cost of allowing one more person to download software is zero. Many college students, through university arrangements with software companies, are able to obtain legal copies of computer programs at a lower cost than others pay for the same products. Microsoft surely makes sufficient profits from customers who pay full price for their software, but price discrimination allows them to increase revenues by also selling to students who would generally not be able to afford the software at full price.

To reduce the degree of inefficiency, government intervention sometimes occurs in markets for artificially scarce goods. Artificially scarce goods are sometimes supplied by monopolies, at least in local markets, such as an area that has only one Internet service provider. In such cases, government regulation could limit excess monopoly profits by setting a price ceiling or requiring that special rates be made available to lower-income consumers. We discuss markets with monopoly suppliers in more detail in Chapter 17.

In other cases, artificially scarce goods are supplied in competitive markets, such as the market for online streaming video services like Netflix, Hulu, and Amazon Prime. Profits in competitive markets will tend to be driven down to "normal" levels (a topic we discuss in Chapter 16). In these markets, there may be less of an imperative for government regulation, especially if the good is not considered a necessity. But even within a competitive environment, markets for artificially scarce goods will still result in inefficiency because at the market price the marginal benefits of additional consumers will exceed the zero marginal cost of additional supply.

Discussion Questions

1. Do you think that price discrimination should be illegal? Does it make economic sense for everyone to pay the same price for something? Do you think that it is fair for everyone to pay the same price for something?
2. Do you think that the profits of a company that provides cable television should be regulated by the government? Is competition in the cable industry sufficient to keep prices reasonable? How is technology changing the nature of competition for video programming?

3. COMMON PROPERTY RESOURCES

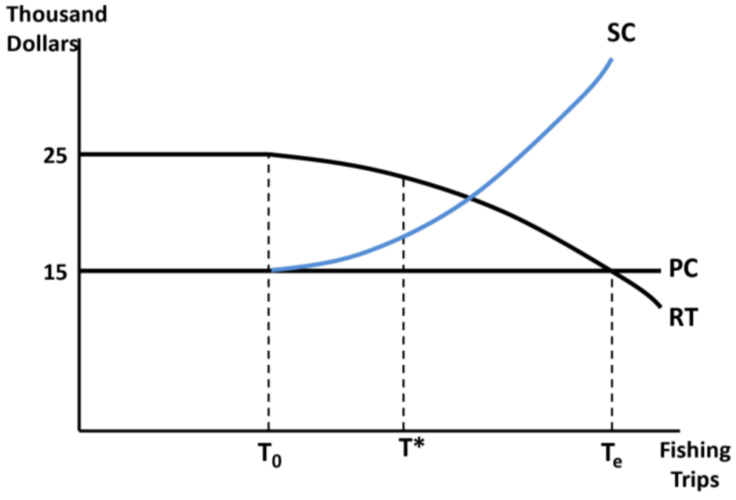
A common property resource is available to essentially anyone, but it cannot be used or enjoyed by multiple people at the same time, at least with the same level of quality. Overuse is often a problem with a common property resource, as when too many people fish the same fishery, want to play sports in the same recreation area, or withdraw groundwater from the same aquifer. We can use economic analysis to examine how this problem arises and what policy solutions may be available.

3.1 MODELING A COMMON PROPERTY RESOURCE

One way to model a common property resource is to realize that, above a certain level of utilization, every user of the resource essentially imposes a cost on other users. In the example of a fishery, if the number of fishing trips is relatively low, adding one more trip is unlikely to affect the catch of other fishers. But above a critical level, each additional fishing trip begins to harm the overall health of the fishery and thus reduces the catch of everyone in the fishery. Each individual fisher will consider only whether he or she is making a profit. So, the fact that others' profits have declined will not be taken into account by additional fishers. This is similar to the idea of a negative externality, but in this case market participants are harming other market participants.

Figure 13.2 models a fishery as an example of a common property resource. The horizontal axis indicates the number of fishing trips taken in the fishery. Assume that it costs $15,000 to operate a fishing trip, considering labor costs, boat payments, fuel, and other costs. (We include the opportunity cost of fishing as part of the $15,000 total—by taking a fishing trip one forgoes the opportunity to engage in the next-best alternative, such as working a job as a teacher or electrician for a salary.) The $15,000 cost represents the private cost of each fishing trip, as shown by the PC line in the graph. Note that the cost to operate a fishing trip is constant, regardless of the number of trips taken.

Figure 13.2. Common Property Model of a Fishery



Next, we need to consider the revenue obtained from each fishing trip. Obviously, this depends on the number of fish caught. For the first few trips, we assume that each fishing trip yields $25,000 in revenues (see curve RT in the graph). When we subtract operating costs, each fishing trip results in $10,000 in profits.

Initially, plenty of fish are available for all fishers, so each additional trip does not affect the catch of anyone else. Until T_0, each fisher is able to obtain revenues of $25,000 per trip. But after the number of trips exceeds T_0, the revenue per trip begins to decline. The fishery is becoming crowded, and because more fishers are competing for limited fish stocks, it becomes more difficult to catch fish. Each fishing trip will still result in a profit but, instead of making a $10,000 profit, each trip will result in a lower profit.

Each fisher will obviously be disappointed to have lower profits. But as long as profits are still positive (RT > PC), there is an incentive for more fishers to take trips to the area. In fact, as fishers begin to realize declining catches, they may be motivated to increase their fishing efforts further in order to catch fish while they still have the opportunity. Note that even if profits per trip are quite small, as we've included opportunity costs in the $15,000 cost per trip, the small profits are still better than the value of the next-best alternative.

We can model the cost that additional fishers impose on others much as we modeled a negative externality. It represents an additional cost above the private cost of operating a boat trip. Above T_0, each additional trip imposes a social cost as shown by curve SC, equal to the reduction in the profits of *all other fishers.* In other words, SC represents the total social cost of operating a boat trip above T_0, considering the private costs of $15,000 plus the external cost equal to the reduction in others' profits.

The socially efficient level of fishing trips is equal to T^*. This is the level at which the profits from a new fishing trip are just enough to compensate for the loss of others' profits. But in an unregulated fishery, there is no reason for fishers to stop at T^*. So long as individual fishers can make profit, the number of fishing trips will continue to increase until we reach T_e. At this point, profit for each fishing trip falls to 0. There will then be no further incentive for additional fishing trips. But at such a high level of fishing effort, social costs are well above revenues, indicating a significant economic inefficiency. In addition, the health of the fishery may begin to decline. Over time, the stock of fish may become so depleted that the fishery crashes, leading to the collapse of the local fishing industry.

3.2 POLICIES FOR COMMON PROPERTY RESOURCE MANAGEMENT

One solution to the problem of the overuse of a common property resource is similar to implementing a Pigovian tax. We could charge a fee for each fishing trip equal to the external cost imposed on others. If fishers had to pay this fee in addition to their out-of-pocket costs of $15,000, we could adjust the fee until we reached the efficient level of fishing trips, *T**.

Another solution is to institute **individual transferable quotas (ITQs)**. These operate much like tradable pollution permits, discussed in Chapter 12. With this approach, an organization managing the resource (such as a government agency) sets the total allowable fishing level, such as the number of fishing trips or the total harvest per season. This level of effort is set low enough to maintain the ecological integrity of the resource. The ITQs can be distributed for free or auctioned off to the highest bidders. If they are auctioned, the proceeds can be used by the government to maintain the quality of the resource or as compensation for those who are forced out of the industry. Holders of ITQs may then use them to fish or offer them for sale to interested parties. The price of an ITQ is not set by the government but allowed to vary depending on supply and demand. ITQ programs for ocean fisheries have been established in several countries, including Australia, Canada, Iceland, and the United States. (For more on ITQs, see Box 13.1.)

individual transferable quota (ITQ): tradable rights to access or harvest a common property resource, such as the right to harvest a particular quantity of fish

BOX 13.1. COMMON PROPERTY RESOURCE MANAGEMENT IN PRACTICE: INDIVIDUAL TRANSFERABLE QUOTAS

Iceland has one of the most extensive systems of individual transferable quotas for its marine fisheries. In 1990 Iceland passed the Fisheries Management Act, which established ITQs for all fisheries, with permits allocated to each fishing vessel based on its proportional share of the national catch during a baseline period. Each year the total allowable catch is determined based on the current scientific evidence regarding the health of each fishery. For example, the allowable cod catch each year is set equal to 20 percent of the “catchable biomass” of the stock. As the health of the cod fishery has improved, the allowable catch has increased—from 130,000 tons in 2007 to over 250,000 tons in 2022.[2]

The ITQs are fully tradable, and even divisible into smaller shares if a fisher wishes to transfer only part of his or her total allocation. Iceland has also implemented regulations that prohibit one company from obtaining an excessive proportion of the permits for a fishery. For example, one company cannot have the rights to more than 12 percent of the national cod allowable catch, or 20 percent of the halibut catch. A separate quota system is in place specifically for smaller boats, to allow the coexistence of both small- and large-scale fishing operations.[3]

A 2017 report from the OECD concluded that as a result of the ITQ system in Iceland “it is clear that the reduction in fishing effort has secured the sustainability of most of the commercially exploited species.”[4] The report also notes that the ITQ system has increased economic efficiency by providing the “correct incentives,” but that protection of the broader marine ecosystem requires additional measures beyond just limiting the catch of marketed fish species.

Although ITQs or other regulations of a common property resource may not be popular with those who are used to accessing the resource for free, these policies are necessary to prevent the unsustainable use of the resource. The overuse of a common property resource has famously been described as the "**tragedy of the commons**" (see Box 13.2). Just as in our externality analysis, the unregulated market outcome with a common property resource will be inefficient.

BOX 13.2. THE TRAGEDY OF THE COMMONS

The term "tragedy of the commons" comes from an influential paper written by ecologist Garrett Hardin in 1968. Discussing the degradation of common grazing land in England, Hardin wrote:

> As a rational being, each herdsman seeks to maximize his gain. . . . [Thus each] herdsman concludes that the only sensible course for him to pursue is to add another animal to his herd. And another, and another . . . But this is the conclusion reached by each and every rational herdsman sharing a commons. Therein is the tragedy. Each man is locked into a system that compels him to increase his herd without limit—in a world that is limited. . . Freedom in a commons brings ruin to all.[5]

Hardin saw the only "solution" to the tragedy of the commons as placing restrictions on the use of common property resources. Such restrictions would most likely need to be legally imposed by a government.

The story told by Hardin was significantly modified by the political scientist Elinor Ostrom, who won the Nobel Memorial Prize in economic science for work "showing how common resources—forests, fisheries, oil fields or grazing lands—can be managed successfully by the people who use them, rather than by governments or private companies."[6] Ostrom's point was that many societies have worked out institutional arrangements that operate with the same result as government regulations, but that depend on social norms and customs instead of laws. In many parts of the world, such systems have endured for centuries.

Ostrom concluded that cooperative local management can be highly effective under certain conditions including:[7]

- Most users of a resource should be involved in devising rules for managing the resource.
- There should be monitors of the resource, accountable to the resource users, who periodically evaluate conditions.
- There should be mechanisms to resolve conflicts that are responsive and low-cost.
- Rules for managing the resource should be adapted to local conditions.
- There should be graduated sanctions for resource users who violate the rules.

Ostrom's framework is not necessarily incompatible with government involvement. She notes that for large-scale common property resources a "nested" approach may be needed involving organizations at different levels. For example, a state or federal government might be needed to administer and enforce an ITQ system, but a local group of fishers might be integral in designing the system and handling disputes.

tragedy of the commons: a situation in which an unregulated common property resource is seriously degraded due to overuse

Discussion Questions

1 Suppose that you and three roommates are living in an apartment or dorm suite with a common area for living, dining, and cooking. Do you think that a "tragedy of the commons" outcome is a likely result without some rules regarding cleaning? What rules would you propose instituting?

2 Suppose that a small fishing community in a developing country has been operating successfully for centuries without any regulations. Each fishing family owns a boat and makes a small profit. However, suppose that climate change reduces the health of the fish stock, and the community is forced to reduce its overall fishing activities. Should the community institute an auction system to allocate fishing rights or begin charging a license fee? Can you think of a fair way to reduce the community's fishing activities?

4. PUBLIC GOODS

Public goods are at the opposite end of the spectrum from private goods. Public goods are both nonexcludable and nonrival. We saw examples of market failure with artificially scarce goods and common property resources. As you might expect, private markets also fail to provide the efficient level of public goods. In fact, even though many people value the benefits of public goods, private markets often fail to provide any public goods at all.

For private goods, the ability to charge a price acts as a way to exclude nonbuyers and thus make a profit. But anyone can enjoy the benefits of a public good without paying, and each additional user does not affect the amount or quality of the good available to others. Consider national defense as an example of a public good. Could we rely on one or more corporations to provide national defense through market supply and demand? Obviously not. No individual would have an incentive to pay because he or she could receive the benefits without paying. Thus the "equilibrium" quantity of public goods in a market setting is normally zero, as no company would want to produce something for which no one is willing to pay. Clearly, this is an example of market failure.

Perhaps we could rely on donations to supply public goods. This is done with some public goods, such as public radio and public television. Also, some environmental groups conserve habitats that, while privately owned, can be considered public goods because they are open for public enjoyment. Donations, however, generally are not sufficient for an efficient provision of public goods. Because public goods are nonexclusive, each person can receive the benefits of public goods regardless of whether he or she pays. Although some people may be willing to donate money to public radio, many others simply listen to it without paying anything. Those who do not pay, but still receive benefits, are called **free riders**.

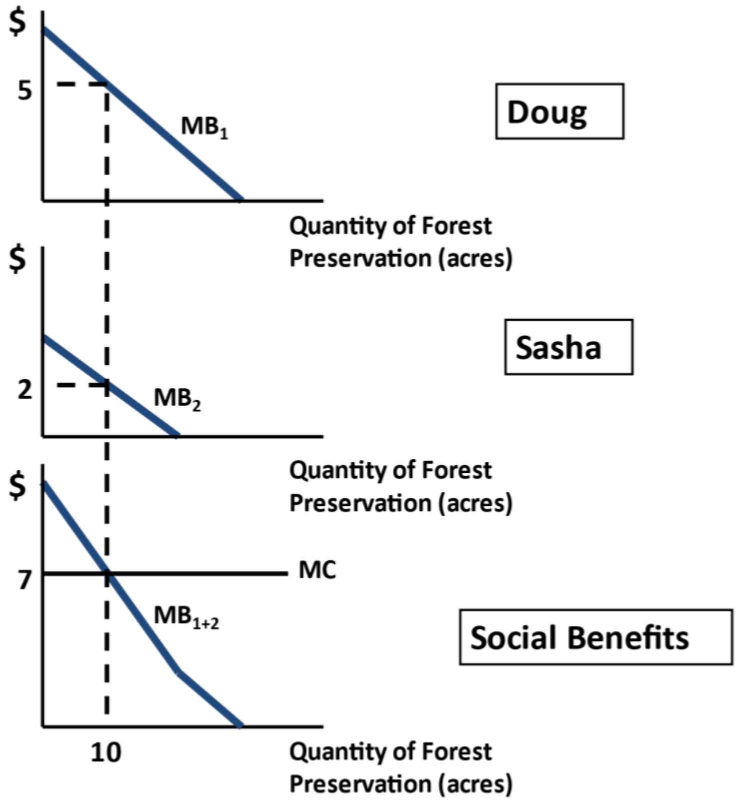
free riders: those who obtain the benefits of a public good without paying anything for it

Although we cannot rely on private markets or voluntary donations to supply public goods, their adequate supply is of crucial interest to society. In democracies, decisions regarding the provision of public goods are commonly decided in the political arena. This is generally true of national defense. A political decision must be made, taking into account that some citizens may favor more defense spending and others less. But a decision must be made, and after the decision is made, we all pay a share of the cost through taxes.

Similarly, decisions on the provision of environmental public goods may be made through the political system. The federal government, for example, decides on funding for national parks. Will more land be acquired for parks? Might some existing park areas be sold or leased for development? In making decisions like this, we need some indication of the level of citizen demand for public goods. What insights can we gain from economic theory?

Recall that in Chapter 5 we referred to a demand curve as both a marginal benefit curve and a willingness-to-pay curve. A consumer is willing to pay, say, as much as $30 for a T-shirt because that is his or her perceived benefit from owning the shirt. But in the case of a public good, the marginal benefits that someone obtains from it are *not* the same as their willingness to pay for it. In particular, the person's willingness to pay is likely to be significantly lower than their marginal benefits, and many will be willing to pay nothing at all.

Figure 13.3. The Benefits of Public Goods



A simple example illustrates this point. Consider a society with just two individuals: Doug and Sasha. Both individuals value forest preservation—a public good. Figure 13.3 shows the marginal benefits that each person receives from the preservation of forest land. As in a regular demand curve, the marginal benefits of each acre preserved decline with more preservation. We see that Doug receives greater marginal benefits than Sasha does for the same level of forest protection. This may be because Doug obtains more recreational use of forests, or it may simply reflect different preferences.

The social marginal benefits from preserved forest land are obtained by the vertical addition of the two marginal benefit curves. In the top graph in Figure 13.3, we see that Doug receives a marginal benefit of $5 for an additional acre of forest preservation if 10 acres are already preserved. Sasha receives a marginal benefit of only $2. The social, or aggregate, benefits of an additional acre of preserved forest are $7, as shown in the bottom graph. The "social benefits" graph represents the addition of the marginal benefits to both Doug and Sasha. In this case, the aggregate curve is kinked (i.e., not straight) because to the right of the kink Sasha's marginal benefits are zero, and the curve showing the value of preserving additional acres reflects only Doug's marginal benefits.

Suppose for simplicity that forest preservation costs society a constant $7/acre for administrative and management costs. This is shown in the bottom graph in Figure 13.3. In this example, the optimal level of forest preservation is 10 acres—the point where the marginal social benefits just equal the marginal costs.

But we have not addressed the question of how much Doug and Sasha are actually willing to pay for forest preservation. As mentioned above, in the case of a public good one's marginal benefit curve is not the same as their willingness-to-pay curve. For example, although Doug receives a marginal benefit of $5 for an acre of forest preservation with 10 acres preserved, he has an incentive to be a free rider and he may be willing to pay less than $5, or even nothing at all.

The problem is that we do not have a market in which people accurately indicate their preferences for public goods. Perhaps we could conduct a survey to collect information on how much people value certain public goods, but sometimes people do not provide accurate responses (recall our discussion of contingent valuation surveys in Chapter 12). Ultimately, decisions regarding public goods require some kind of social deliberation. One option is to rely on elected officials to make public goods decisions for their constituents. Another is to rely on a democratic process such as direct voting or local town meetings.

Suppose that we correctly determine that the appropriate level of forest preservation in Figure 13.3 is 10 acres. At a constant marginal cost of $7/acre, we need to raise $70 in revenues to pay for preservation. We could tax Doug and Sasha $35 each to cover these costs. Doug receives at least $5 in benefits for every acre preserved, or a total of at least $50 in benefits, so he may not object to the $35 tax. However, Sasha receives significantly lower benefits, and she may view the tax as excessive. Nonetheless, the tax is necessary to achieve the optimum public benefit.

Now, let us extend our two-person example to the entire population of a country. Marginal benefits from forest preservation, and other public goods, are likely to vary considerably across households. It is clearly impractical to assess the actual marginal benefit of each household for different public goods. Again, a society-wide decision must be made to allocate tax revenues toward different public goods. After this decision has been made, some people might think that they have to pay too much overall, or object to the allocation among different goods. But assessing a broad tax on all households is essential for achieving adequate funding for public goods. Debates regarding efficiency and fairness in the case of public goods are thus inevitably both political and economic in nature.

Discussion Questions

1. Some people have suggested that certain public lands would be managed more efficiently if they were auctioned off to the highest bidders. In theory, the highest bidder would put the land to its highest-valued use. Employing a market valuation, that use might be logging or developing the land for vacation homes. Such an auction would provide the government with revenue, which could be used for socially beneficial purposes or for lowering taxes. Do you think that some public lands should be sold to private interests?
2. Consider the provision levels of the following public goods in society: national defense, public education, environmental quality, and highways. Do you think that the current "supply" of each of these goods is too high, too low, or about right? What factors do you think determine the amount of resources that are allocated toward each of these goods? Do policies need to be changed to adjust the allocation?

5. CLIMATE CHANGE

The issue of global warming, more accurately described as **climate change**,[*] has been called "the greatest market failure the world has ever seen."[8] Developing an adequate policy response to climate change brings together much of our discussion over the last two chapters regarding externalities, environmental issues, common property resources, and public goods. Climate change also raises important questions about fairness between rich and poor countries, about the present versus the future, and about how to devise policies in the presence of uncertainty.

climate change: long-term changes in global climate, including warmer temperatures, changing precipitation patterns, more extreme weather events, and rising sea levels

The scientific consensus on climate change is well-established. A 2021 article found that over 99 percent of peer-reviewed scientific publications studying the issue conclude that human emissions of various gases, primarily carbon dioxide (CO_2), are significantly impacting the global climate system.[9] According to the World Meteorological Organization, each decade since the 1980s has been warmer than the previous one, and the seven warmest years on record have all been since 2015.[10]

Climate change has significant economic costs. According to a 2019 analysis by the International Monetary Fund, climate change could reduce global economic production by over 7 percent in 2100 without sufficient reductions in greenhouse gas emissions.[11] Other research suggests the damages will be even larger. A 2021 report estimated the damages from climate change without more aggressive policies to be 11-18 percent of the world economy, by as soon as 2050, amounting to as much as $23 trillion in reduced global economic output.[12] The impacts of climate change will disproportionally impact lower-income countries, with damages of 17-37 percent of GDP in Southeast Asia and 14-28 percent of GDP in Africa. The negative consequences of climate change are already occurring. According to a 2017 report, the damages from climate change are currently averaging $240 billion per year in the

[*] We use the term "climate change" instead of "global warming" because, in addition to warmer average temperatures, numerous other impacts are expected to occur, including precipitation changes, rising sea levels, and changes in storm frequency and severity.

United States, effectively offsetting about 40 percent of annual economic growth in the United States.[13]

Policy responses to limit the future damages from climate change need not sacrifice economic vitality. In 2021 the managing director of the International Monetary Fund, Kristalina Georgieva, stated that there "is no question that climate change matters to growth, employment and financial stability."[14] She went on to say:

> It is critical … to address climate change and speedily put in place policies that can make a difference. [We] we need market signals that work for the new climate economy, not against it. … IMF staff research projects that green supply policies could raise global GDP by about 2 percent this decade and create millions of new jobs.[15]

In our analysis of climate change we first explore the data and projections on the topic, then we discuss economic analyses of climate change, and finally we summarize current policy approaches to respond to climate change and limit its negative impacts.

5.1 CLIMATE CHANGE DATA

Humans can influence the global climate by the emissions of various **greenhouse gases**. These gases act much like the glass in a greenhouse—allowing solar radiation to penetrate but then trapping it and increasing temperatures. Although various greenhouse gases exist naturally in the earth's atmosphere and make life possible on earth, human activities have increased the concentration of many of these gases and introduced greenhouse gases into the atmosphere that do not occur naturally. The major greenhouse gas emitted by humans is carbon dioxide (CO_2), which is formed when fossil fuels (coal, oil, and natural gas) are burned. Other important greenhouse gases include methane, nitrous oxide, and chlorofluorocarbons (CFCs).[†]

greenhouse gases: gases such as carbon dioxide and methane whose atmospheric concentrations influence global climate by trapping solar radiation

Global emissions of CO_2 have increased significantly over the past several decades, from about 20 gigatons (billion metric tons) annually in the 1980s to 36 gigatons in 2021.[16] While the COVID-19 lockdowns reduced global CO_2 emissions by 5.4 percent in 2020, emissions rebounded by 4.9 percent in 2021, a "bigger than expected" increase.[17]

The world's largest emitters of CO_2 are China (31 percent of global emissions), the United States (14 percent), India (7 percent), and Russia (5 percent). While the non-OECD countries are responsible for two-thirds of current global carbon emissions, high-income countries have been responsible for more cumulative emissions to date, with the United States being the largest emitter—responsible for over 20 percent of all emissions from 1850 to 2021.[18]

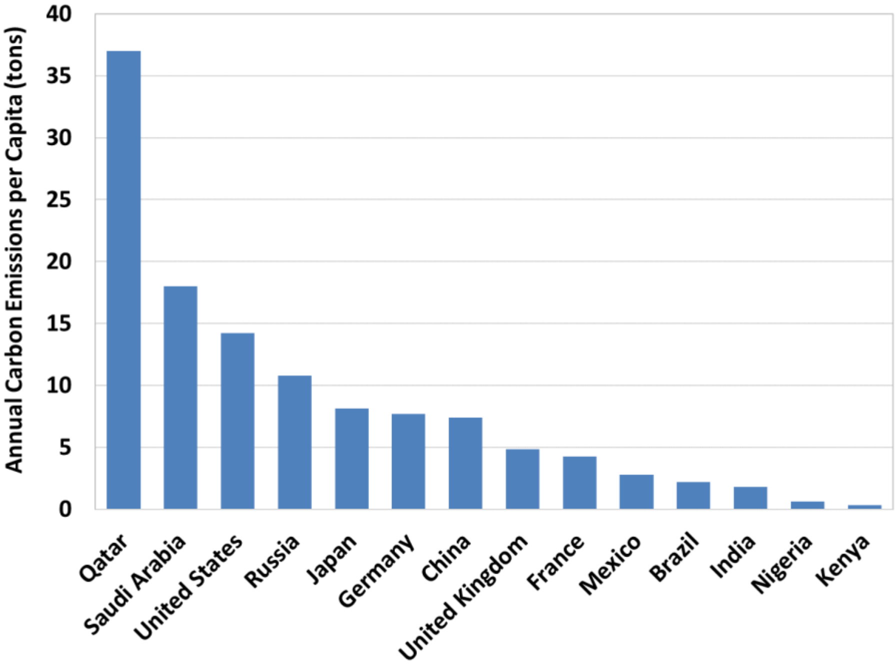
Further, CO_2 emissions *per capita* are much higher in developed countries and will continue to be so for the foreseeable future. For example, annual emissions per capita are currently about 14 tons in the United States, 8 tons in Germany, 7 tons in China, 2 tons in India, and 0.6 tons in Nigeria, as shown in Figure 13.4.[19] This disparity

[†] CFCs have also been implicated in depletion of the ozone layer, a critical layer of the atmosphere. It is important to note that degradation of the ozone layer, while serious, is an issue almost entirely unrelated to global climate change.

in emissions per capita roughly reflects the global disparity in income. Simply requiring all countries to reduce emissions by the same proportion would reinforce current global income inequalities by limiting the development options available to developing countries.

CO_2 and other greenhouse gas emissions remain in the atmosphere for a long time, decades or even centuries. This means that even if we reduce annual emissions by 50 percent or more, total concentrations will continue to rise. The atmosphere can be viewed as a bathtub with a very, very slow leak (representing the long-term natural decay of greenhouse gases). As long as we keep adding more water (i.e., greenhouse gases) beyond a slight trickle to the bathtub, its level will continue to rise. To reduce current levels, it would be necessary to achieve a net removal of greenhouse gases from the atmosphere.

Figure 13.4. Carbon Emissions per Capita, 2020, Select Countries



Source: Global Carbon Atlas, http://www.globalcarbonatlas.org/en/CO2-emissions.

As atmospheric concentrations of greenhouse gases increase, the world is expected to become warmer, on average. Not all regions will warm equally, and some regions may actually become cooler. Warmer average temperatures increase evaporation, which in turn leads to more frequent precipitation, but again all regions will not be affected equally. In general, areas that are already wet will become wetter and dry areas will become drier. Climate change is also expected to result in more frequent and more intense tropical storms. The melting of polar ice caps and glaciers is contributing to rising sea levels, and this trend will intensify with further warming. Arctic and Antarctic temperatures are rising more rapidly than the global average. Sea levels are also rising because the volume of ocean water expands when it is heated.

Global average temperatures have already increased by about 1 degree Celsius (1.8 degrees Fahrenheit) since the start of the 20th century.[20] At the 2015 international climate meeting in Paris, nearly 200 nations agreed that it was necessary to limit the eventual warming to "well below" 2 degrees Celsius, and to "pursue efforts" to limit the warming to 1.5 degrees Celsius, based on the scientific consensus that warming above these levels is likely to cause dangerous economic and ecological impacts.[21]

The Intergovernmental Panel on Climate Change (IPCC) was established in 1988 by the United Nations and the World Meteorological Organization to assess the science of climate change. A 2021 IPCC report concludes that it is "unequivocal that human influence has warmed the atmosphere, ocean and land. Widespread and rapid changes in the atmosphere, ocean, cryosphere and biosphere have occurred."[22] The report also concludes that the Paris climate targets will be exceeded during the 21st century "unless deep reductions in CO_2 and other greenhouse gas emissions occur in the coming decades."[23]

5.2 ECONOMIC ANALYSIS OF CLIMATE CHANGE

Strong policy action to reduce emissions of greenhouse gases could avoid the most damaging effects of climate change. Scientists at the IPCC estimate that global CO_2 emissions must fall by at least 50 percent by 2050 in order to limit the temperature increase to no more than 2 degrees Celsius, and would need to fall to nearly zero to achieve the 1.5°C target.[24] But most countries are still highly dependent on fossil fuels as an energy source, with coal, oil, and natural gas providing 81 percent of the world's energy supplies.[25] Transitioning to a low-carbon economy will require major investment in energy efficiency and renewable energy.

Various economic studies have analyzed climate change using the techniques of cost-benefit analysis, which was discussed in Chapter 12. Cost-benefit analysis of climate change is particularly difficult for two main reasons: the high degree of uncertainty about future impacts and the long time period of the analysis. Most of the costs of responding to climate change are borne in the short term, while most of the benefits (in terms of avoided damages) occur in the long term. Thus the choice of a discount rate is critical.

Virtually all economists agree that carbon emissions represent a negative externality and that a market-based policy such as a Pigovian tax or a tradable permit system should internalize this externality. However, there is a lively debate among economists about how aggressive such policies should be. Early economic studies of climate change suggested a relatively modest carbon tax, perhaps around \$20–\$40 per ton of carbon emitted (a \$30 per ton tax on carbon would increase the price of gasoline by about 8 cents per gallon).

The economic debate over climate change changed significantly in 2006 when Nicholas Stern, a former chief economist at the World Bank, released a 700-page report, sponsored by the British government, titled "The Stern Review on the Economics of Climate Change." Publication of the Stern Review generated significant media attention and intensified the debate over climate change in policy and academic circles. Unlike previous studies, the Stern Review strongly recommended immediate and substantial policy action.

What accounts for the difference between the Stern Review and most earlier analyses? The primary difference was that Stern applied a lower discount rate of 1.4 percent, compared to 3–5 percent in most other studies. Stern argued that his discount rate reflects the view that each generation should have approximately the same inherent value. Stern's analysis also incorporated the precautionary principle (discussed in Chapter 12), in that he placed greater weight on the possibility of catastrophic damages.

Some economists criticized the Stern Review for overstating the damages from climate change and underestimating the costs of reducing carbon emissions.[26] But as we'll discuss, the costs of transitioning away from fossil fuels are declining faster than most experts expected. Also, over time most economists have lowered their discount rate recommendations for economic analyses of climate change. A 2001 survey revealed that economists' average discount rate recommendation was 4.0 percent. A similar survey in 2015 produced an average recommendation of 2.3 percent.[27]

The most recent economic analyses generally conclude that it is economically efficient to meet the targets under the Paris Climate Agreement. A 2021 study incorporating updated data on the persistence of climate change damages finds that "substantially greater near-term mitigation efforts" are economically justified.[28] A 2021 economic analysis published by the OECD recommends "rapid and deep cuts in greenhouse gas emissions to achieve climate neutrality globally."[29] Finally, another 2021 analysis concludes:

> No country is immune to the effects of climate change, and no action is not an option. … Climate change will have economic costs even if the Paris Agreement goals are met, but the costs could be significantly more severe in alternative scenarios. Hence, the Paris targets remain the best achievable outcome.[30]

5.3 CLIMATE CHANGE POLICY

Because climate change can be considered a very large environmental externality associated with carbon emissions, economic theory suggests a carbon tax as an economic policy response. Alternatively, a tradable permit system (also known as cap-and-trade) could be applied to carbon emissions.

As discussed in Chapter 12, a tax offers price certainty, while a tradable permit system offers emissions certainty. If you take the perspective that price certainty is important because it allows for better long-term planning, then a carbon tax is preferable. If you believe that the relevant policy goal is to reduce carbon emissions by a specified amount with certainty, then a cap-and-trade approach is preferable, although it may lead to some price volatility.

Both approaches have been used. Carbon taxes on fossil fuels have been instituted in several countries, including Costa Rica, France, Germany, Japan, and South Africa.[31] The European Union instituted a cap-and-trade system for carbon emissions in 2005. The system covers more than 11,000 facilities that collectively are responsible for nearly half the EU's carbon emissions. In 2012 the system was expanded to cover the aviation sector, including incoming flights from outside the EU. The goal of the EU program is to reduce greenhouse gas emissions by at least 40 percent relative to 1990 levels by 2040.[32] The state of California instituted a cap-and-trade system in 2013 for electrical utilities and large industrial facilities, with a goal of reducing greenhouse gas emissions in 2050 by 80 percent, relative to 1990 levels.[33]

According to most scientists, an adequate policy response to climate change will require strong action at the international level. Each individual country has very little incentive for reducing its emissions if other countries do not agree to similar reductions. Action to reduce climate change can be regarded as a public good that also generates a positive externality. As we have noted, in the case of public goods, the problem of free riders means that they will not be provided effectively without collective action.

The 2015 Paris Climate Agreement provides the framework for an international response to climate change. As mentioned, the goal of the agreement is to limit eventual warming to below 2 degrees Celsius, or even better to below 1.5 degrees Celsius. Rather than imposing universal climate policy mechanisms, such as a global carbon tax, or legally binding emissions targets, the Paris agreement is built upon voluntary "nationally determined contributions" (NDCs). Each participating country is free to set its own emissions targets, with some targets being relatively ambitious while others are comparatively modest. For example, Costa Rica has set strong interim targets along a path to become fully carbon neutral (no net carbon emissions) by 2050.[34] Most other countries' NDCs have been rated "insufficient" by the nonprofit organization Climate Action Tracker, with some countries such as Russia, Iran, and Thailand rated "critically insufficient". .

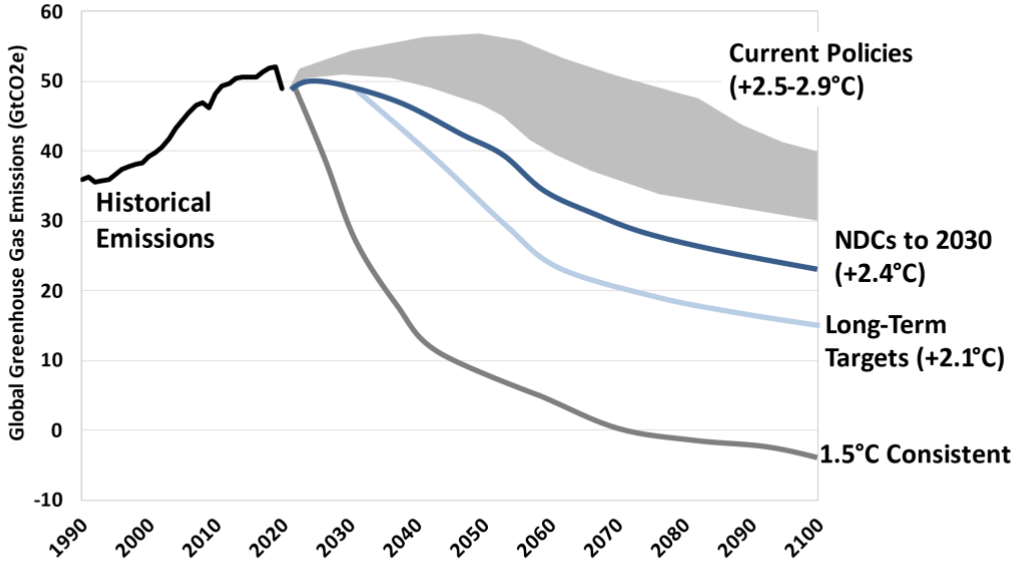
Each country is free to set its own national policies to meet its NDC, and there are no penalties for countries that fail to meet their targets. Still, the Paris agreement represents the most comprehensive international climate framework so far; the 1997 Kyoto Protocol only included developed nations. The Paris agreement called for developed nations to contribute $100 billion per year by 2020 to help developing countries transition away from fossil fuels and adapt to the impacts of climate change. This target was missed, largely because the United States under the Trump administration failed to meet its commitments, but was reaffirmed at the 2021 international climate meeting in Glasgow, along with an additional $40 billion to support climate adaptation.

In the 2021 Glasgow Climate Pact, 197 countries agreed to provisions including:[35]

- The 2015 Paris agreement specified that countries would be encouraged to strengthen their NDCs every 5 years. Recognizing that existing NDCs are not sufficient to meet climate targets, countries agreed to reconsider their NDCs more frequently, starting in 2023.
- For the first time, countries agreed to "phase down" coal use. However, this represented a weaker goal than the initial phrasing to "phase out" coal use, after objections from China and India.
- The agreement urges developed nations to at least double their climate financing for developing countries by 2025.
- Countries agreed to phase out fossil fuel subsidies that artificially lower the prices of coal, oil, and natural gas. However, a target date was not set.

While many countries submitted more ambitious NDCs in Glasgow, further emissions reductions will be needed to meet the objective of limiting eventual warming to 2 degrees Celsius or less, as shown in Figure 13.5. Prior to the Glasgow Climate Pact, under existing national policies global greenhouse gas emissions are projected to continue to increase until at least 2030 and potentially until 2050 (the top gray-shaded region), with an expected global temperature increase between 2.5 and 2.9 degrees Celsius. If all countries meet their current NDCs through 2030, then global emissions will peak by 2030, and the median temperature increase will be 2.4 degrees Celsius (the dark blue line). Beyond these NDCs, many countries have set long-term emissions targets; for example, both the United States and the European Union aim to be carbon neutral by 2050. If such long-term targets are met, then global emissions will fall more rapidly (the light blue line) and the temperature increase is expected to be 2.1°C. Achieving the 1.5°C target would require dramatic emissions reductions starting immediately, falling below zero after 2070 (Negative net emissions are possible if large amounts of carbon are removed from the atmosphere through expansion of forests or other methods.)

Figure 13.5. Global Greenhouse Gas Emissions and Temperature Increase Under Alternative Scenarios



Source: Climate Action Tracker, https://climateactiontracker.org/global/temperatures/.
Note: Emissions data include carbon dioxide and other greenhouse gases converted to carbon dioxide equivalents.

5.4 ECONOMICS OF RENEWABLE ENERGY

Achieving climate policy goals will require a major shift away from fossil fuels toward renewable energy sources such as solar and wind. As noted, carbon taxes and tradable permits are two effective economic policies that can help to motivate this transition. While such policies have not been implemented to the extent necessary to meet global climate targets, recent market forces have nonetheless begun driving an energy revolution in favor of renewables.

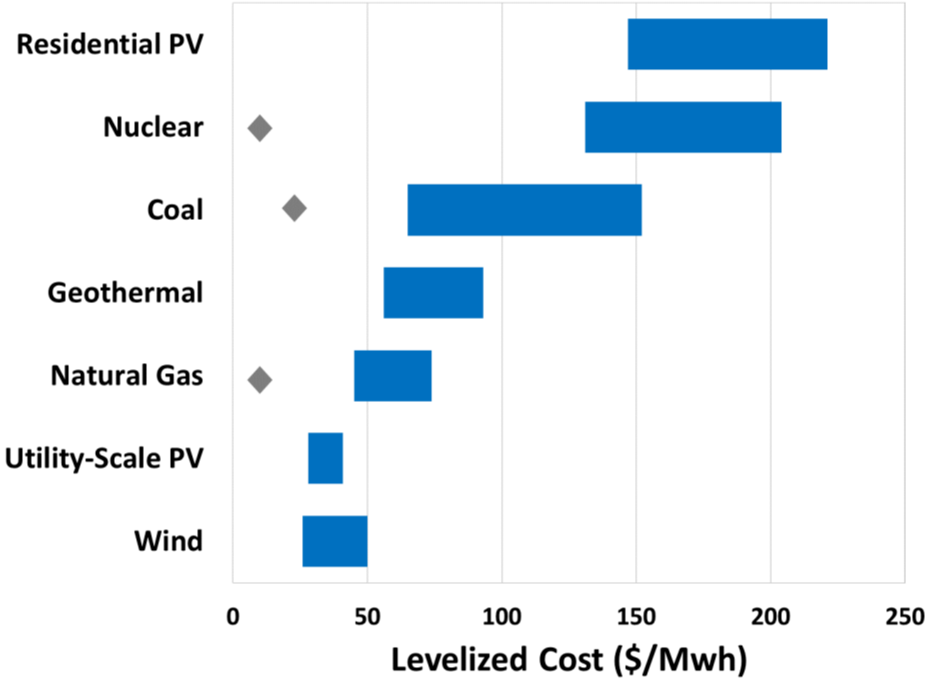
The dominance of fossil fuels has primarily been attributed to their cost advantage, with coal, and more recently natural gas, historically being the cheapest sources to generate electricity. That is no longer true in much of the world, as the cost of solar and wind energy has declined steeply—much faster than most experts expected. Between 2009 and 2021 the average cost of generating electricity from wind power declined by 72 percent, and the cost of utility-scale solar power fell by 90 percent.[36] As shown in Figure 13.6, wind and solar are now the two cheapest energy sources on average globally, even without subsidies. ("Levelized cost" means costs including construction and operating costs, discounted over time.)

Further, the cost of installing new wind and solar is increasingly becoming cheaper than just the *marginal* operational cost of fossil fuel and nuclear energy, excluding the initial cost of constructing the power plant (shown by the diamond markers in Figure 13.6). In other words, in many places in the world it is cheaper to simply stop using existing fossil fuel and nuclear power plants and instead invest in new renewable energy sources.

As a result of these dramatic cost declines, along with policy changes, renewable energy is expected to account for 95 percent of all new energy capacity globally between 2021 and 2026.[37] The great transition away from fossil fuels toward renewable energy and battery storage is inevitable:

> [T]he greening of the world's electricity system is unstoppable, thanks to rapidly falling costs for solar and wind power, and a growing role for batteries, including those in electric vehicles, in balancing supply and demand.[38]

Figure 13.6. Cost Comparison of Electricity Generation from Different Energy Sources, 2021



Source: Lazard, 2021.
Note: Diamond markers indicate marginal energy costs excluding construction costs.

However, renewable energy, including hydroelectricity, currently only provides about 13 percent of the world's power generation.[39] Without ambitious action, it will take considerable time until we obtain the majority of our energy from renewables. According to the International Energy Agency, renewables would provide only 26 percent of global energy supplies in 2050 under existing national policies.[40] If countries meet their current NDCs, the share of renewable energy in 2050 will rise to 37 percent, indicating that the majority of global energy will still come from fossil fuels unless further steps are taken. Yet there is reason for optimism given that past forecasts have consistently under-estimated the growth and price declines of renewable energy—see Box 13.3.

A final point is that while further technological advances will likely speed the transition away from fossil fuels, there is no economic justification for waiting. As detailed in a 2017 paper, a complete global transition to renewable energy by 2050 is economically feasible using existing technologies.[41] The authors conclude that such a transition will avoid about 4.6 million premature air pollution deaths per year, create a net gain of 24 million full-time jobs, save an average of about $85 per person annually in energy costs, and possibly allow the aggressive 1.5 degrees Celsius target to be met. The great energy transition is already underway, but economic policies will make a very large difference in the scale and timing of the transition.

BOX 13.3. CONSISTENT INACCURACIES IN RENEWABLE ENERGY FORECASTS

The U.S. Energy Information Administration (EIA) and the International Energy Agency (IEA) publish annual projections for renewable energy. Many people, from academics to politicians, rely upon these forecasts. But in recent years an increasing number of energy experts have been pointing out that the EIA and IEA forecasts have consistently underestimated the growth and price declines of renewable energy. Consider just a few examples:

- In 2000 the EIA forecast that under a "high renewables case" wind generation capacity in the U.S. would reach nearly 20 gigawatts in 2020.[42] Actual wind capacity in 2020 exceeded 100 gigawatts in the U.S.
- In 2010 the EIA forecast that under a favorable "low renewables cost" scenario non-hydropower renewable energy capacity in the U.S. would grow by about 60 percent from 2015 to 2035.[43] From 2015 to only 2021 wind energy production in the U.S. increased by 80 per cent and solar energy production grew by a factor of 4.6.[44]
- In 2010 the IEA forecast that global energy production from wind and solar could grow by nearly a factor of 10 from 2008 to 2035 under a "new policies scenario" to encourage a transition to renewable energy.[45] From 2008 to 2020 alone, global wind and solar energy production increased by a factor 10.5.[46]
- In 2015 the IEA predicted that by 2040 the price of solar energy would decline by about 40%.[47] From 2015 to 2021 alone, the price of solar energy fell by 45%![48]

Many other examples could be presented to show that the growth of wind and solar generation capacity, and the decline in renewable prices, has consistently exceeded the EIA's and IEA's most optimistic forecasts. Part of the problem is that the agencies' models are built to favor the status quo. But as one energy expert explains regarding the EIA's forecasts, "They have constraints that tie their hands a bit, but that doesn't explain why they're so consistently wrong in the same direction. They're not just conservative about change. They're ignoring the evidence of what's actually happening in the market."[49] A 2016 journal article suggests several improvements to the EIA's energy projection methodology, concluding that unless "projections of renewable energy are greatly improved, the reliability of [the EIA's] electricity projections is inherently low."[50]

Even with a rapid transition to renewables, an effective response to climate change will require action in other areas, including:

- Forest management: Trees are a carbon "sink", extracting and storing carbon from the atmosphere. When forests are degraded, cut, or burned, their carbon is released into the atmosphere, exacerbating climate change. The United Nations estimates that 11 percent of global carbon emissions are a result of deforestation and forest degradation. The Paris climate targets will be "practically impossible to achieve without reducing emissions from the forest sector."[51]
- Agriculture and soils: About 30 percent of global greenhouse gas emissions come from the agriculture sector.[52] As raising livestock is particularly carbon

intensive, reducing meat consumption will lower overall emissions. Also, improved agricultural practices can significantly increase the storage of carbon in cropland soils.[53]

- Energy efficiency: More than half of all energy used by the global economy is "wasted" due to inefficient technologies and equipment. For example, the global transportation sector, with its heavy reliance on internal combustion engines, is only about 25 percent efficient (with most of the energy lost as waste heat).[54] Electric vehicles are much more efficient, converting close to 80 percent of electricity into energy to move the vehicle.[55] Other dramatic efficiency gains are possible with better technologies for heating, air conditioning, and industrial production.

A combination of these policies has the potential to achieve the very ambitious targets necessary to hold global warming to no more than 1.5° Celsius. In choosing and implementing policies, economic analysis is key to understanding which policies can deliver the best results at least cost.

Discussion Questions

1 How serious a problem do you think climate change is? Compare your judgment of this based on news reports and the economic studies that have tried to evaluate the costs and benefits of climate change. How effective do you think economic analysis has been in approaching the problem?

2 Which policies do you think are most likely to be effective in responding to climate change? Given the political resistance to taxes, what do you think would be the best strategy for achieving reduction of greenhouse gas emissions?

REVIEW QUESTIONS

1. What are the two characteristics of private goods? Provide some examples.
2. What are the two characteristics of public goods? Provide some examples.
3. What are the two characteristics of common property goods? Provide some examples.
4. What are the two characteristics of artificially scarce goods? Provide some examples.
5. How do economists define congestion?
6. What is the supply curve for an artificially scarce good?
7. Why does the private provision of an artificially scarce good result in economic inefficiency?
8. What is price discrimination?
9. How can we model the market for a common property resource?
10. How can we determine the utilization or harvest for a common property resource without any regulation?
11. How do we determine the efficient outcome for a common property resource?
12. What policies can be implemented in the case of a common property resource?
13. What is the tragedy of the commons?
14. What is the likely equilibrium outcome for a public good in a private market?
15. Can voluntary donations result in the efficient provision of public goods?
16. What are free riders?
17. How can we model the demand for a public good in a simple society with two individuals?

18. Why do someone's marginal benefits differ from his of her willingness to pay in the case of a public good?
19. What policies are needed to provide for the efficient provision of public goods?
20. What do most economic analyses of climate change conclude? What are some major differences?
21. What are some economic policies to address climate change?
22. What are some recent trends in the price of different energy sources?

EXERCISES

1. For each of the following examples, discuss whether it is a private good, a public good, a common property resource, or an artificially scarce good. Note that some examples may be considered more than one type of good.
    a. Seats in a movie theater
    b. Traffic lights
    c. A lake on private land
    d. A lake on public land
    e. Cars owned by a car rental company
    f. The water in a currently pure river, which can be used for drinking water as well as waste disposal
    g. A hospital that provides free health care to low-income households

2. An underground aquifer in a developing country is available to all farms in a small community. Assume that it costs 50 pesos per day to operate a pump that can extract groundwater from the aquifer. The value that a farm can obtain by using or selling the water depends on how many farms extract water, as given in the table below.

Number of households extracting water	Revenue per day per household (pesos)	Profit per day per household (pesos)	Total profit (pesos)
1	100		
2	100		
3	100		
4	90		
5	80		
6	65		
7	55		
8	40		
9	20		

    a. Assuming that there is no regulation of the aquifer, how many farms will extract groundwater? Assume that as long as each farm is making a profit, there is an incentive for more farms to extract water. Fill in the last column of the table to help you answer this question.
    b. Is this unregulated outcome economically efficient? Explain.
    c. What would be the economically efficient level of groundwater extraction (number of farms extracting water)? Hint: calculate total profit by multiplying number of farms by profit per farm and see where total profit reaches a maximum. At this point, the extra profit made by adding one more farm is just balanced by the losses to other farms.

3. The marginal benefits of wildlife habitat preservation in a society with just two individuals, Katya and Miguel, are given in the table below.

Acres of wildlife habitat	Katya's marginal benefits (dollars)	Miguel's marginal benefits (dollars)
1	50	30
2	40	25
3	30	20
4	20	15
5	10	10
6	0	5

   a. Draw a graph showing the social marginal benefits of wildlife preservation.
   b. Suppose that wildlife preservation costs $40 per acre. How many acres of wildlife habitat should be preserved in this society?
   c. What policy would you propose to achieve the efficient provision of wildlife habitat?
   d. Which individual do you think would be less willing to support your policy proposal? Explain.

4. Match each concept in Column A with an example in Column B.

Column A	Column B
a. A private good	1. A policy solution to the tragedy of the commons
b. A free rider	2. National defense
c. Price discrimination	3. The primary factor on which some economists disagree regarding climate policy
d. A public good	4. Your shoes
e. An artificially scarce good	5. Someone who listens to public radio without contributing to it
f. Individual transferable quotas	6. Charging airline passengers different fares
g. The discount rate	7. The WiFi signal at a hotel that charges for Internet access

REFERENCES

Agnarsson, S., T. Matthiasson, and F. Giry. 2016. "Consolidation and Distribution of Quota Holdings." *Marine Policy*, 72:263–270.

Amelung, W., D. Bossio, W. de Vries, and 17 other authors. 2021. "Towards a Global-Scale Soil Climate Mitigation Strategy." *Nature Communications*, 11:5427.

Anonymous. 2021. "COP26: What Was Agreed at the Glasgow Climate Conference? BBC News, November 15.

Anonymous. 2017. "Global Wind and Solar Costs to Fall Even Faster, While Coal Fades Even in China and India." Bloomberg New Energy Finance, June 15.

BP. 2021. *Statistical Review of World Energy 2021*. London.

Drupp, Moritz, Mark Freeman, Ben Groom, and Frikk Neske. "Discounting Disentangled." Centre for Climate Change Economics and Policy, Working Paper No. 195, November.

European Commission. 2016. *The EU Emissions Trading System (EU ETS)*. https://ec.europa.eu/clima/sites/clima/files/factsheet_ets_en.pdf.

Evans, Simon. 2021. "Analysis: Which Countries Are Historically Responsible for Climate Change?" CarbonBrief, October 5.

Food and Agriculture Organization of the United Nations (FAO). 2021. *The Share of Food Systems in Total Greenhouse Gas Emissions. Global, Regional and Country Trends, 1990–2019*. FAOSTAT Analytical Brief Series No. 31. Rome.

Gilbert, Alexander Q., and Benjamin K. Sovacool. 2016. "Looking the Wrong Way: Bias, Renewable Electricity, and Energy Modelling in the United States." *Energy*, 94:533-541.

Georgieva, Kristalina. 2021. "No Time to Waste." *Finance and Development*, September:4-5.

Grunwald, Michael. 2015. "Why Are the Government's Energy Forecasts So Bad?" Politico, June 24.

Hardin, Garrett. 1968. "The Tragedy of the Commons." *Science*, 162(3859):1243–1248.

Harrington, Rebecca. 2015. "The World Wastes More Energy than it Uses Every Year." *Business Insider*, November 30.

Harvey, Fiona. 2021. "Helping Poorest Tackle Climate Crisis Will Boost Global Growth, Says IMF Head." *The Guardian*, January 24.

Hausfather, Zeke. 2021. "Global CO_2 Emissions Have Been Flat for a Decade, New Data Reveals." CarbonBrief, November 4.

Herman, Yves. 2021. "Factbox—What's in the Glasgow Climate Pact?" Reuters, November 15.

Intergovernmental Panel on Climate Change (IPCC). 2021. *Climate Change 2021: The Physical Science Basis, Summary for Policymakers*. Geneva, Switzerland.

International Energy Agency (IEA). 2021a. *Key World Energy Statistics 2021.* Paris.

International Energy Agency (IEA). 2021b. *Renewables 2021*. Paris.

International Energy Agency (IEA). 2021c. *World Energy Outlook 2021*. Paris.

International Energy Agency (IEA). 2015. *World Energy Outlook 2015*. Paris.

International Energy Agency (IEA). 2010. *World Energy Outlook 2010*. Paris.

Jacobson, Mark Z., Mark A. Delucchi, Zack A.F. Bauer, and 24 other authors. 2017. "100% Clean and Renewable Wind, Water, and Sunlight All-Sector Energy Roadmaps for 139 Countries of the World." *Joule*, 1:108–121.

Kahn, Matthew E., Kamiar Mohaddes, Ryan N. C. Ng, M, Hashem Pesaran, Mehdi Raissi, and Jui-Chung Yang. 2019. Long-Term Macroeconomic Effects of Climate Change: A Cross-Country Analysis." IMF Working Paper WP/19/215, October.

Lazard. 2021. *Lazard's Levelized Cost of Energy Analysis – Version 15.0*. October 28.

Lynas, Mark, Benjamin Z. Houlton, and Simon Perry. 2021. "Greater than 99% Consensus on Human Caused Climate Change in the Peer-reviewed Scientific Literature." *Environmental Research Letters*, 16(2021):114005.

Mendelsohn, Robert. 2008. "Is the *Stern Review* an Economic Analysis?" *Review of Environmental Economics and Policy*, 2(1):45-60.

OECD (Organisation for Economic Co-operation and Development). 2021. *Managing Climate Risks, Facing up to Losses and Damages*, OECD Publishing, Paris.

OECD (Organisation for Economic Co-operation and Development). 2017. "Sustaining Iceland's Fisheries through Tradeable Quotas." OECD Environment Policy Paper No. 9.

Ostrom, Elinor. 1990. *Governing the Commons: The Evolution of Institutions for Collective Action.* Cambridge University Press, Cambridge, UK.

Schultes, Anselm, Franziska Piontek, Bjoern Soergel, and 5 other authors. 2021. "Economic Damages from On-going Climate Change Imply Deeper Near-term Emission Cuts." *Environmental Research Letters*, 16:104053.

Stern, Nicholas. 2007. *The Economics of Climate Change: The Stern Review.* Cambridge University Press, Cambridge, UK.

Swiss Re Institute. 2021. *The Economics of Climate Change: No Action Not an Option*. Zurich, Switzerland, April.

U.S. Energy Information Administration (EIA). 2021. *Annual Energy Review*. Washington, DC.

U.S. Energy Information Administration (EIA). 2010. *Annual Energy Outlook 2010*. Washington, DC.

U.S. Energy Information Administration (EIA). 2000. *Annual Energy Outlook 2000*. Washington, DC.

Watson, Robert, James J. McCarthy, and Liliana Hisas. 2017. "The Economic Case for Climate Action in the United States." Universal Ecological Fund (FEU-US), September.

World Meteorological Organization (WMO). 2022. "2021 One of the Seven Warmest Years on Record, WMO Consolidated Data Shows." WMO Press Release, January 19.

NOTES

[1] Artificially scarce goods are also called club goods.
[2] Government of Iceland, Fisheries Management, https://www.government.is/topics/business-and-industry/fisheries-in-iceland/fisheries-management/.
[3] Agnarsson et al., 2016.
[4] OECD, 2017.
[5] Hardin, 1968, p. 1244.
[6] http://www.nbcnews.com/id/33275953/ns/business-stocks_and_economy/t/two-americans-win-nobel-economics-prize/#.WgnaAHZrxeM.
[7] Ostrom, 1990.
[8] Stern, 2007.
[9] Lynas *et al*., 2021.
[10] WMO, 2022.
[11] Kahn *et al*., 2019.
[12] Swiss Re Institute, 2021.
[13] Watson *et al*., 2017.
[14] Harvey, 2021.
[15] Georgieva, 2021.
[16] Carbon emissions data from Global Carbon Atlas for 2020, http://www.globalcarbonatlas.org/en/CO2-emissions.
[17] Hausfather, 2021.
[18] Evans, 2021.
[19] IEA, 2017.
[20] U.S. EPA, Climate Change Indicators: U.S. and Global Temperature.
[21] United Nations, https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement.
[22] IPCC, 2021, p. 4.
[23] Ibid., p. 14.
[24] Ibid.
[25] IEA, 2021a.

[26] See, for example, Mendelsohn, 2008.
[27] Drupp *et al*., 2015.
[28] Schultes *et al*., 2021.
[29] OECD, 2021.
[30] Swiss Re Institute, 2021, p. 26.
[31] https://en.wikipedia.org/wiki/Carbon_tax.
[32] European Commission, 2016.
[33] https://www.arb.ca.gov/cc/capandtrade/capandtrade.htm.
[34] https://climateactiontracker.org/countries/costa-rica/.
[35] Anonymous, 2021; Herman, 2021.
[36] Lazard, 2021.
[37] IEA, 2021b.
[38] Anonymous, 2017.
[39] BP, 2021.
[40] IEA, 2021c.
[41] Jacobson *et al*., 2017.
[42] U.S. EIA, 2000, Figure 83.
[43] U.S. EIA, 2010, page 69.
[44] U.S. EIA, 2021.
[45] IEA, 2010, Table 2.1.
[46] BP, 2021.
[47] IEA, 2015, Figure 1.3.
[48] Lazard, 2021.
[49] Grundwald, 2015.
[50] Gilbert and Sovacoo, 2016, p. 533.
[51] UN-REDD Programme, “About REDD+”, https://www.unredd.net/about/what-is-redd-plus.html.
[52] FAO, 2021.
[53] Amelung *et al*., 2021.
[54] Harrington, 2015.
[55] U.S. Department of Energy, https://www.fueleconomy.gov/feg/evtech.shtml.